Red Hill Administrative Order on Consent, Attachment A Scope of Work Deliverable

Section: 5.3.2 Destructive Testing Scope of Work

In accordance with the Red Hill Administrative Order on Consent, paragraph 9, DOCUMENT CERTIFICATION

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information including the possibility of fines and imprisonment for knowing violation.

Signature: ______________________

CAPT Richard Hayes, CEC, USN
Regional Engineer, Navy Region Hawaii

Date: 5/30/2017

RED HILL BULK FUEL STORAGE FACILITY

SCOPE OF WORK FOR DESTRUCTIVE TESTING

Administrative Order on Consent (AOC) and Statement of Work (SOW)
Section 5.3.2

May 30, 2017

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GENERAL DESTRUCTIVE TESTING STATEMENT OF WORK

1.0 BACKGROUND

On December 9, 2013, the Navy placed one of the tanks (Tank No. 5) at the Red Hill Bulk Fuel Storage Facility back into service after it had undergone routine scheduled maintenance. The maintenance work consisted of cleaning, inspecting, repairing the tank, and certifying, by an API inspector, that it was suitable for service. Upon placing Tank No. 5 back into service, the Navy commenced filling the tank with JP-8 fuel. On January 13, 2014, Navy discovered a loss of fuel from Tank No. 5, immediately notified the State of Hawaii Department of Health (DOH) and the United States Environmental Protection Agency (EPA), and defueled the tank.

In response to the fuel release reported by the Navy, an Administrative Order on Consent (AOC) between the Navy, Defense Logistics Agency (DLA), EPA, and the DOH provides for the performance by the Navy and DLA of a release assessment, response(s) to release(s), and actions to minimize the threat of future releases in connection with the field-constructed bulk fuel underground storage tanks (USTs), at the Red Hill Bulk Fuel Storage Facility located near Pearl Harbor, on the island of Oahu in the State of Hawaii.

2.0 PURPOSE AND SCOPE

The purpose of the deliverables to be developed and work to be performed in accordance with AOC-SOW Section 5.3 is to verify the findings of the Corrosion and Metal Fatigue Practices Report through the use of destructive testing on at least one tank at the Facility.

2.1 AOC-SOW Requirement

Within ninety (90) days from the final Destructive Testing Scoping Meeting, Navy and DLA shall submit a Destructive Testing Scope of Work, including a plan for implementation and a proposed schedule, to the Regulatory Agencies for approval. The Scope of Work shall detail planned destructive testing to be conducted on at least one (1) tank at the Facility. Once approved by the Regulatory Agencies, Navy and DLA shall implement the Scope of Work in accordance with the approved schedule.

Within twenty-four (24) months from the Regulatory Agencies' approval of the Destructive Testing Scope of Work, Navy and DLA shall submit the Destructive Testing Results Report to the Regulatory Agencies for approval. It is important to note that all destructive testing work under this section must likely be completed twenty (20) months after approval of the Destructive Testing Scope of Work to allow ample time for preparation of the final report, review by the Regulatory Agencies, incorporation of any recommendations, and approval of the final report by the twenty-four (24) month timeframe.

2.2 Goals and Desired Outcomes

The goals and desired outcomes of the efforts to be done under this section are to:

- Validate the results of Non-destructive examination (NDE) inspection technologies, specifically the NDE process used at Red Hill as described in Section 3.0. Validate the continued use of the NDE process at Red Hill as well as other tanks in the Department of Defense (DoD) and industry.
- Characterize steel material.
- Record observations/chemical characteristics of the concrete behind the liner
- Analyze corrosion rate calculation procedures and recommend improvements as warranted.
- Evaluate results against current corrosion mitigation practices and recommendations for modifications/improvements to tank inspection, repair, and maintenance (TIRM) procedures and tank upgrade alternatives (TUA).

3.0 DESTRUCTIVE TESTING DISCUSSION

NDE is a variety of industry methods used to evaluate the condition of fuel storage tanks and pipelines. Technologies are used to scan plate steel and welds for indications as well as to quantify the size of indications and amount of metal loss. The intent of this section is to validate the results of NDE technologies and processes used to scan the Red Hill storage tanks. Assessment of the reliability of the NDE technologies may eliminate the need for destructive testing on other tanks scheduled for TIRM.

3.1 Tank Selection Rationale

As all parties desire this effort to be completed as soon as practicable, selection of the tank(s) to be tested is an important consideration. Different tanks will be out of service at different times, and tank selection must also consider the ability to complete the destructive testing and the Destructive Testing Report within the AOC-SOW specified timeframe. Navy and DLA operational requirements must also be considered. ***Figure 1*** (flow chart superimposed on AOC-SOW timeline) presents tank selection options within the AOC-SOW timeline, and ***Figure 2*** is a flowchart of the coupon selection process.

The Navy desires to minimize the amount of destructive testing on operational fuel storage tanks required to meet the requirements of the AOC-SOW. Tanks can only be taken out of service based upon Navy operational schedules, and not all tanks will be available prior to the required completion date of the Destructive Testing Report. To this end there are several key decision processes in determining the destructive testing process. The quantity and size of coupons is somewhat dependent upon tank selection. ***Table 1*** provides a summary of the rationale for tank selection with detailed discussions in the paragraphs that follow.

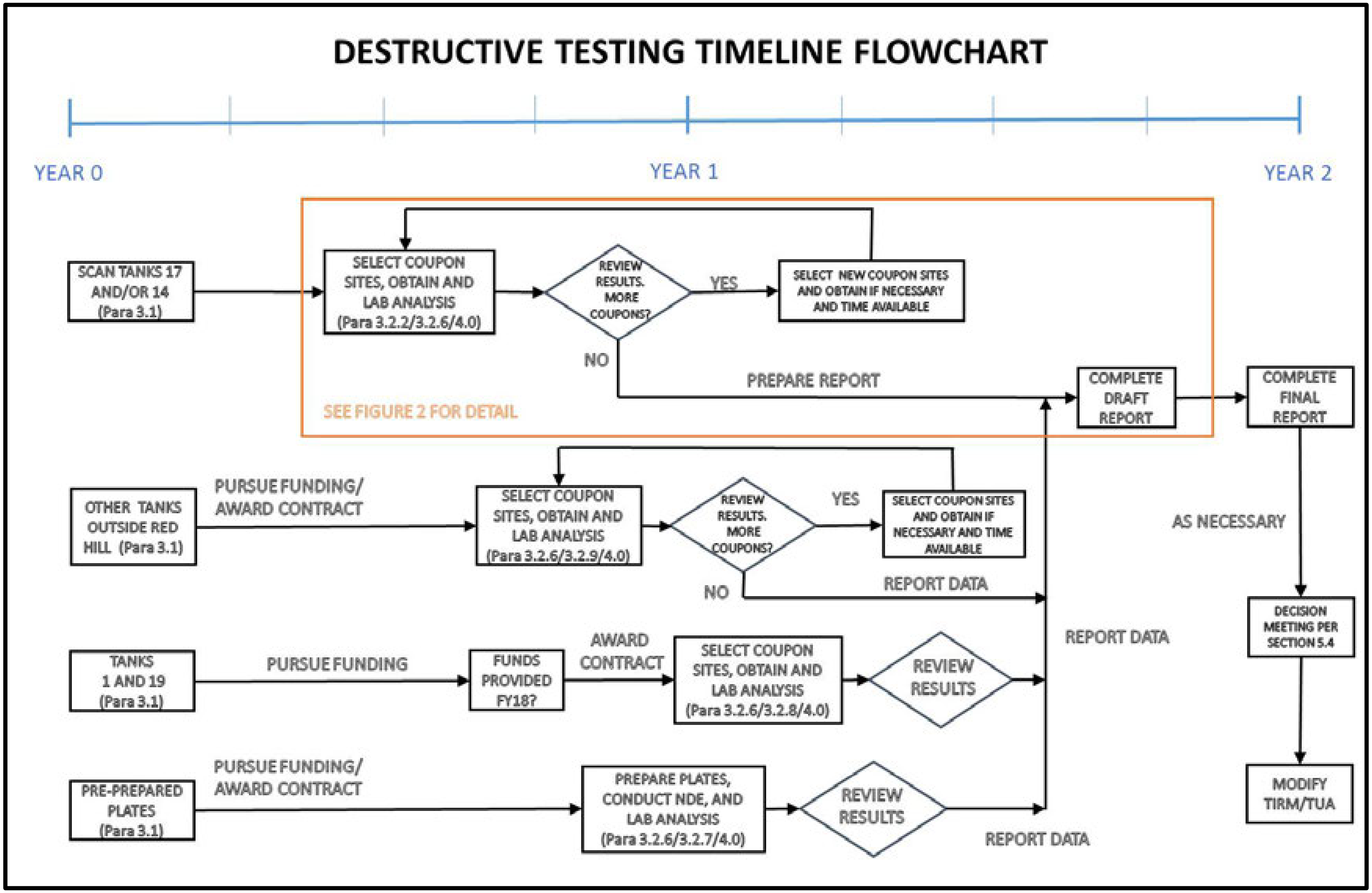

Figure 1. Destructive testing timeline and flowchart

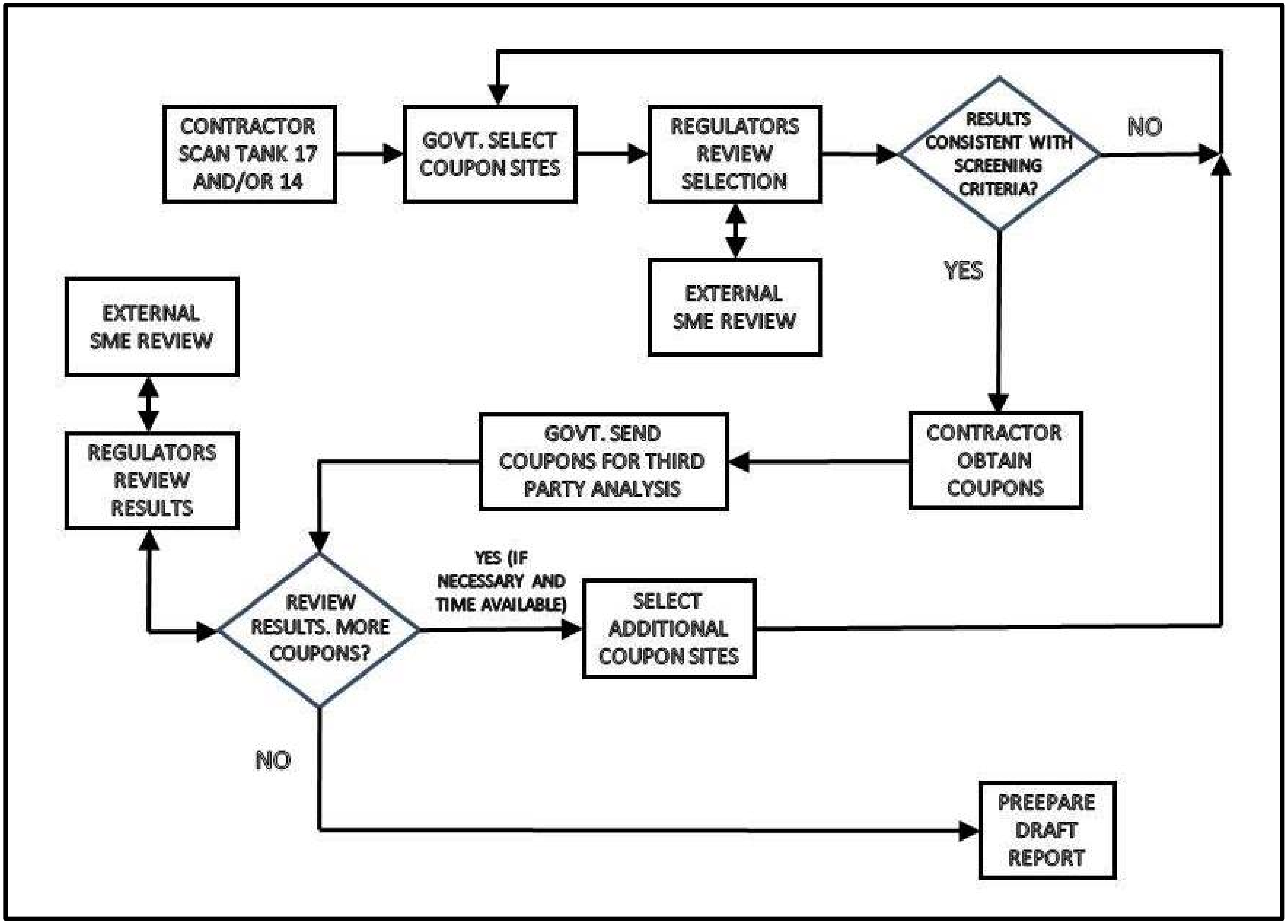

Figure 2. Coupon selection process flowchart

Table 1. Summary of Tank Selection Rationale

Tank ID	Feasibility	Rationale
Tanks 17/14	Best alternatives	• Minimal impact on operational requirements • Already out of service • NDE scheduled for summer of 2017
Tank 5	Not Feasible	• Delays in placing tank back in service detrimentally impairs ability to take next tank out of service for inspection/repair • Modifications to tank will void repair warranties and contractor's API inspector certification that tank can be returned to service
Tank 1	Likely not feasible	• Tank permanently out of service - no operational budget for tank. Special funding (limited dollar amount) must be requested one fiscal year in advance • Condition of lattice tower unknown and timeframe to establish safe access for work will be very lengthy • No operational ventilation system and lights • Any testing will be limited to lower part of lower dome
Tank 19	May be possible	• No operational budget for this tank. Special funding (limited dollar amount) must be requested one fiscal year in advance • Timeframe to establish safe shell access will be lengthy
Others outside Red Hill	May be Possible	• Tank must be available for testing within AOC-SOW timeframe • Funding/new contract vehicle must be available for testing within AOC-SOW timeframe

Tanks 17 or 14 are proposed for the following reasons:

Pros:

- Minimal impact on operational requirements. Tanks 17 and 14 are already out of service and NDE is scheduled to commence in the summer of 2017.
- This presents the best alternative to comply with the AOC-SOW timeline with minimal impact to Navy and DLA operations. The TIRM report identifies constraints in removing tanks from service

Cons:

- None at this time for the purposes of this AOC-SOW Section 5.3 effort.

The two tanks are proposed based upon operational schedule and AOC-SOW Section 5.3 timeline, not on representative condition. The AOC-SOW Section 5.3 scope of work is to validate the non-destructive evaluation (NDE) technology, not the representative condition of the tank. Coupons will be taken from the first of the two tanks that will be available for testing. If additional destructive testing is necessary based on the results of destructive testing in the first tank, then coupons will be taken from the same or the other tank. In addition, the current TIRM schedule identifies two other tanks which will be taken out of service shortly with a targeted return to service timeframe 2019. These tanks can be considered if the destructive testing can be completed in time to complete the Destructive Testing Report. Due to the size of these tanks as well as operational requirements, the process to empty, clean and prepare a tank for safe entry can take several months.

It has been suggested that destructive testing be conducted in Tank 5. While Tank 5 has been scanned and repaired and would also be favorable to meet the AOC-SOW timeline, further delays in placing this tank back into service would detrimentally impair the ability to take the next tank out of service for inspection and repair. In addition, any modifications to the tank will void warranties on the repairs done on this tank and the contractor's API inspector certification that the tank can be returned to service.

Tanks 1 and 19 are available for testing considerations with some caveats:

Pros:

- Tanks are permanently out of service.
- Very little impact to Navy and DLA operations.
- Do not need to scan the entire tank. Can conduct NDE scans on small sections then remove coupons to validate the NDE scans.

Cons:

- Because the tanks are permanently out of service, there is no operational budget for these tanks, and special funding will need to be requested to conduct the testing on these tanks. The process to obtain the funding will take time, and it may not be possible to complete testing within the timeframe required to be able to complete the Destructive Testing Report.
- The timeframe to enter, establish safe shell access, and conduct work in Tank 1 will be very lengthy (including time to obtain funding, award contract and prepare tank for safe entry). Refer to the ventilation, degassing, and confined space requirements in the TIRM Report.
- Since Tank 1 has been inactive for a long while, the conditions of the lattice tower inside the tank are unknown, and there are no operational ventilation system and lights. Testing, if at all feasible, will be limited to the lower part of the lower dome.
- The timeframe to establish safe shell access in Tank 19 will be lengthy (including time to obtain funding, award contract and prepare tank for safe entry). Refer to the ventilation, degassing, and confined space requirements in the TIRM Report.

Consideration of Tanks 1 and 19 must be done in parallel with testing in Tanks 17 or/and 14 in the event that the Government budgeting process will not permit accomplishment within the AOC-SOW timeline.

In addition, other tanks in the Navy inventory are being considered. Tank bottoms of aboveground storage tanks are representative candidates to assess NDE reliability and can increase the size of the dataset. Testing of other tanks will require a new contracting vehicle and additional funding above budgeted requirements for the tanks. Therefore consideration of other tanks must be done in parallel with testing in Tanks 17 or/and 14 in the event that the Government budgeting and contracting process will not permit accomplishment within the AOC-SOW timeline.

3.2 Coupons for Testing

The Navy desires to meet the requirements of the AOC-SOW and minimize the amount of destructive testing on operational fuel storage tanks. A solid steel plate, somewhat homogeneous in material content, with minimal welding provides better integrity than a plate with numerous welds and patch plates with different material content as a result of excessive destructive testing. Each coupon removal and repair must be carefully considered to avoid future tank integrity issues. Solid metal plates provide the best tank integrity while excessive sizes and quantities of coupons with large quantities of welded areas may reduce the long term integrity of the tank. To this end there are several key decision points in determining the destructive testing process.

3.2.1 Current Red Hill NDE Process

The intent of this AOC-SOW Section is to validate the results of the Red Hill tank NDE inspection process and technology. The tank inspection process is briefly described in Section 2.5 of the Corrosion Practices and Metal Fatigue Report. Chapter 4 and Appendix BD of the Tank Inspection, Repair, and Maintenance Report provide detailed descriptions of the Red Hill tank inspection processes, and are summarized in ***Table 2***. Additional details are provided in the paragraphs that follow Table 2. The NDE processes used by the Navy are not unique to the Navy but are well established and utilized by industry for NDE of a variety of industrial infrastructure. The processes have been determined to be the best available and practicable technology for conducting thorough tank inspections of the large and unique Red Hill storage tank steel liners.

Table 2. Red Hill Tank NDE Process

NDE Inspection Type	Primary NDE Testing	Secondary NDE Testing
Pitting	Low Frequency Electromagnetic Technique	Traditional Ultrasonic Testing Methods
Wall Thinning	Low Frequency Electromagnetic Technique	Traditional Ultrasonic Testing Methods
Welds	Balanced Field Electromagnetic Technique	Shear Wave Ultrasonic Testing or Magnetic Particle Testing

Pitting. Pitting, a localized form of corrosion, presents a higher risk to the integrity of a Red Hill tank steel liner than wall thinning or metal fatigue. While general external corrosion rates of the liner are low due to the passivating nature of concrete, a pit caused by corrosion can occur at an accelerated rate. Non-destructive examination (NDE) and testing for the entire tank shell, upper and lower domes is conducted by the Low Frequency Electromagnetic Technique (LFET) which examine the walls and components for remaining wall thickness measurements. ***Figure 3*** is an example scan. The results of the LFET inspections are used to determine actionable locations for repairs. Based on initial LFET scan results, proofs by traditional ultrasonic testing (UT) is conducted to verify/validate extent of underside corrosion before selecting defects for repair.

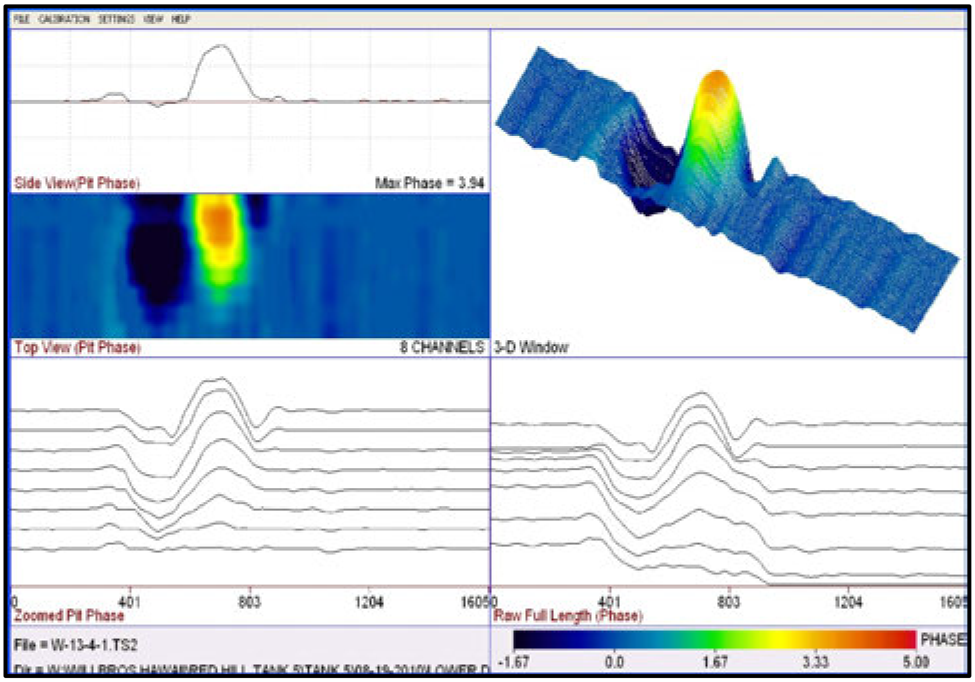

Figure 3. Example of an LFET scan indicating underside corrosion exhibiting 0.178 inch remaining wall thickness.

Wall Thinning. Similar to pitting, LFET examination for the entire tank shell, upper and lower domes is conducted. ***Figure 4*** is an example scan. The results of the LFET inspections are used to determine actionable locations for repairs. Based on initial LFET scan results, proofs by traditional ultrasonic testing is conducted to verify/validate the extent of underside corrosion before selecting defects for repair. This process also provides good confidence in the scanning process for defects.

Welds. NDE of all welds is conducted, by the Balanced Field Electromagnetic Technique (BFET). ***Figure 5*** is an example scan. A special electromagnetic probe is based on the principle of achieving a "balanced field" for the probe. A single element probe of this type was used to detect linear indications. The results of the BFET are used to determine actionable locations for repairs. Based on initial BFET scan results, proofs by Shear Wave Ultrasonic Testing (SWUT) or Magnetic Particle Testing (MT) is conducted to verify/validate extent of weld discontinuities, linear indications and limits for acceptability before selecting defects for repair.

Since the Navy NDE processes already include validation of the LFET and BFET inspections by proof testing with UT or MT, the processes also provide good confidence in the scanning process for defects. Therefore, examination and testing of a smaller number of samples of the shell from specific locations presenting the highest risk to corrosion is proposed.

To date, there has been no inspection data that suggest any metal fatigue issues in the tanks. If under certain rare operational circumstances where the steel plates experience cyclic loads or stresses, fatigue would be expected to culminate in cracks in the tank steel plate welds. Destructive testing of weld linear indications will be conducted only when NDE results indicate a need for such investigation.

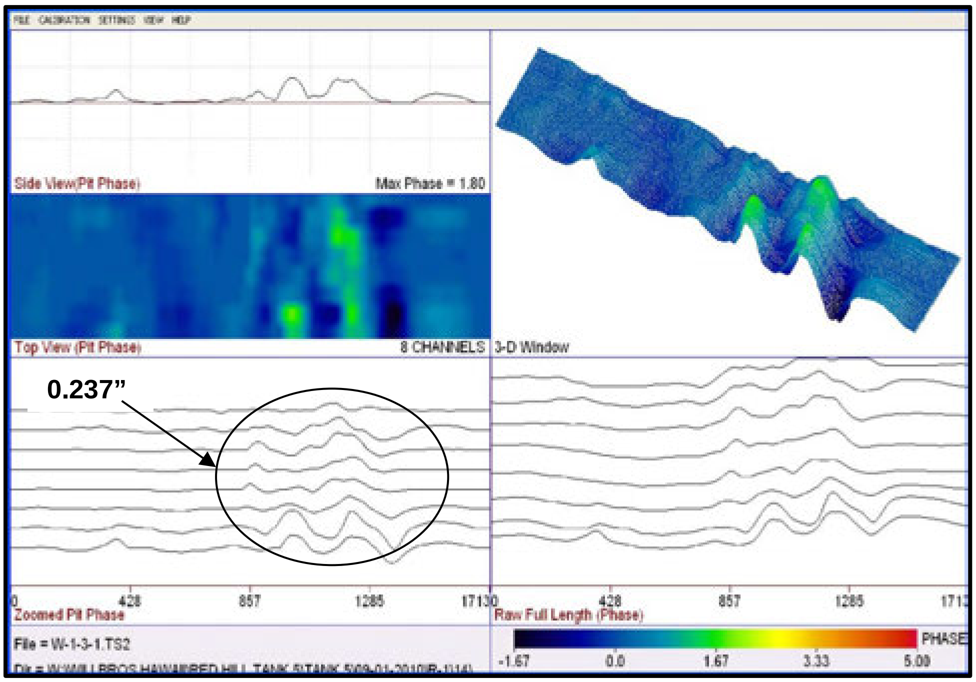

Figure 4. Example of an LFET scan indicating underside corrosion exhibiting 0.237 inch remaining wall thickness.

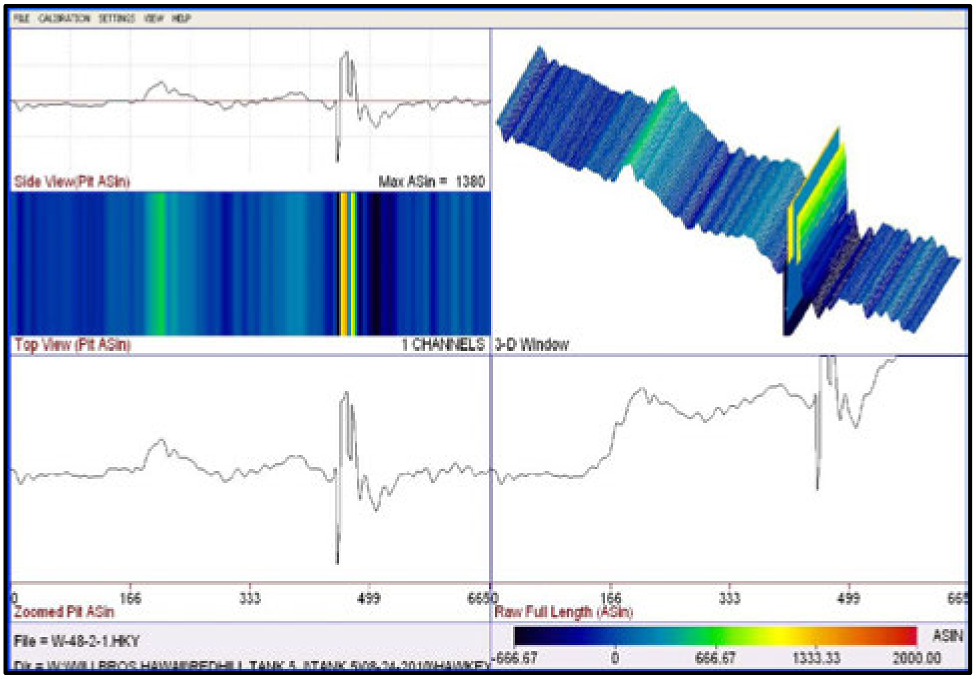

Figure 5. Waveform indicating undercutting of a weld 0.125 inch deep and 5.0 inches long.

3.2.2 Statistical Analysis

The coupons and NDE results will be analyzed and validated by utilizing the Parametric Receiver Operating Characteristic (ROC) curve analysis. Since it was developed in World War II, the Receiver Operating Characteristic curve has been the universally accepted way of analyzing classification errors. The data required to perform an ROC curve analysis are NDE and Destructive Evaluation (DE) results of a continuous quantity, such as remaining thickness. These results are the by-product of NDE and DE.

Simulated data for an ROC curve analysis are in ***Figure 6***. Points are pairs of DE and NDE thickness measurements on each of 27 coupons. The horizontal line at 100 mils is the NDE threshold for a positive indication; points below the line are positive indications (of excessive thinning). The vertical line is the gold standard for excessive thinning. Points to the left indicate truly excessive thinning and need to be repaired.

False negatives are the two observations in the North-West quadrant, the estimated false negative rate is therefore 2 out of 5 or 40%. The ROC curve is generated by changing the excessive thinning threshold from 100 to some other value. For example, example, moving the line up to 105 mils produces zero false positives and negatives but moving it to 110 mils adds one false negative, so the optimal threshold would be about 105 mils. Parametric ROC curve analysis involves fitting a regression line to the graph and using the estimated slope, intercept, and residual standard deviation to compute false positive rates and false negative rates. Parametric ROC curve analysis makes much more efficient use of data than simply counting points in the four quadrants.

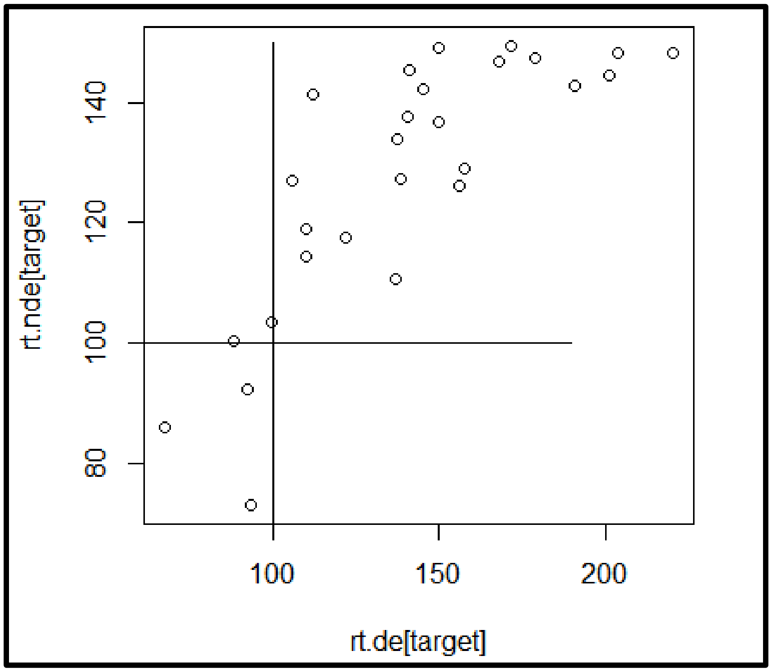

Figure 6. Simulated Data from Targeted Sub-Coupons

3.2.2.1 Screening Criteria

The intent is to validate action items per current TIRM procedures, and summarized in the screening criteria below. Accuracy of detecting smaller defects is less of a concern, as they are not expected to cause integrity issues at least until the next tank inspection based upon current, conservative corrosion rate calculation methodology.

- Pitting. Analyze scans for indications of back side thinning or pitting with remaining thickness in the range of 170 mils and 100 mils. Current TIRM procedures indicate actionable items for remaining thickness less than 170 mils. Accordingly, 170 mils thickness is selected as the upper limit. The lower limit of 100 mils represents the minimum thickness for tank integrity. Based on current corrosion rate calculations (subject to change) 170 mils is the conservative minimum thickness required to ensure thickness will be at least 100 mils until the next inspection.

- Thinning. Analyze scans for indications of back side thinning or pitting with remaining thickness in the range of 170 mils and 100 mils. Current TIRM procedures indicate actionable items for remaining thickness less than 170 mils. Accordingly, 170 mils thickness is selected as the upper limit. The lower limit of 100 mils represents the minimum thickness for tank integrity per API 653. Based on current corrosion rate calculations (subject to change) 170 mils is the conservative minimum thickness required to ensure thickness will be at least 100 mils until the next inspection.

- Welds. Analyze BFET inspection/proof testing for indications of non-full penetration welds, discontinuities, and defects that exceed ASME code limits per current TIRM procedures.

Separate ROC curve analyses will be conducted for each of the three NDE processes. Sampling will be deemed adequate when there are sufficient data points to generate a regression line to the graph from which a realistic estimated slope, intercept, and residual standard deviation can be used to compute false positive rates and false negative rates.

3.2.3 Coupon Locations

Locations for selection of coupons for testing will be based on data from visual and LFET and BFET inspections of the tank for selection of target areas based on reported reductions in wall thickness, pitting (corrosion implications), and weld defects. Minimal amount of sampling is planned for the upper dome. Although the upper dome is scanned and repaired, current Navy operational procedure is to not fill the tanks into the upper dome.

3.2.4 Coupon Size

- Coupons need not all be the same size, and the size may be dependent upon the location and the NDE scans
- Navy desires to limit the size of the coupons in order to minimize length of repair welding
- If a coupon is too large, the replacement plate must be rolled to match the curvature of the existing steel and handled with specialized rigging.
- TIRM report identifies a coupon size of 8 inches by 4 inches. Based upon initial findings, adjustment of the coupon quantities or sizes may be necessary.
- If repairs to any of the tanks are occurring during the timeline of the report, and the nature of the repair requires removal of the plate section, the removed section may be documented as a coupon. As indicated in the TIRM report, some flaws deemed necessary to be repaired will typically be repaired by welding a patch plate over the area.

3.2.5 Quantity of Coupons

Due to the huge surface area presented by the steel tank liner, acquiring sufficient number of samples for worthwhile statistical analysis of a particular tank's status and behavior with respect to corrosion (and fatigue) would be an inordinate task.

From a statistical standpoint, a sampling percentage of 1 – 10% of the total surface area of tankage has been suggested. With tankage surface areas of over 80,000 SF, one percent of the total area is about 800 SF which would be the equivalent of 50 coupons of size 4 feet by 4 feet. This large quantity and size of coupons suggested would require significant amounts of additional time beyond the typical TIRM schedule that would detrimentally impact the mission of the facility and the overall Navy/DLA desired timeline to inspect the rest of the Red Hill tanks and determine their condition. The TIRM Report describes, in detail, the numerous operational, physical, contractual, and tank inspection frequency constraints.

Clearly for the Red Hill Tanks, determination of the number and size of coupons must include good engineering judgments in combination with statistical methods to provide sufficient data for the planned statistical analysis. Rules of thumb are important because they promote discussion that facilitates the selection of an optimal sample size. Also, assumptions and many other considerations affect sample-size selection. These considerations include: sampling time, purpose, approach, method, capturing a reasonable amount of data variation, the type of model being developed, the underlying data distribution—such as normal or exponential—and the type of statistical tools being used.

The initial proposed location is either Tank 17 or 14 which are both already out of service for inspection and present the best opportunity to complete the work within the time frame required to comply with the AOC-SOW. Removal of at least five (5) but no more than 12 coupons is planned. The size of the coupons may be as large as 12 inches by 12 inches and will be selected to include, as much as practicable, multiple indications of backside thinning, back side pitting, and linear indication flaws. The intent is to obtain sufficient data points for the ROC curve analysis, while minimizing the number of coupons cut out of the operational tank. In addition the coupons will be selected to include areas of non-defect indications and qualitatively analyzed against the NDE scans. ***Figure 7*** is an example of a non-indication LFET scan. NAVFAC EXWC intends to send the coupons to a third party laboratory for material analysis, surface characterization and ROC curve analysis.

3.2.6 Coupon Selection Process

The protocol for selection of coupon sites and obtaining coupons is as follows:

- After the LFET and BFET inspections, the contractor, under Government direction, will conduct proof testing at coupon/sample sites as necessary per normal tank inspection procedures. Proof testing includes ultrasonic testing, SWUT, and visual confirmation by American Society for Nondestructive Testing (ASNT) SNT-TC-1A Level II inspectors as listed in Table 2.
- The Government will review the Inspection Results and will determine the coupon locations in accordance with the screening criteria listed in paragraph 3.2.2.1.
- The Government will present coupon locations along with rationale for selection (refer to screening criteria in paragraph 3.2.2.1) to the regulators for review and comment prior to actual sampling.

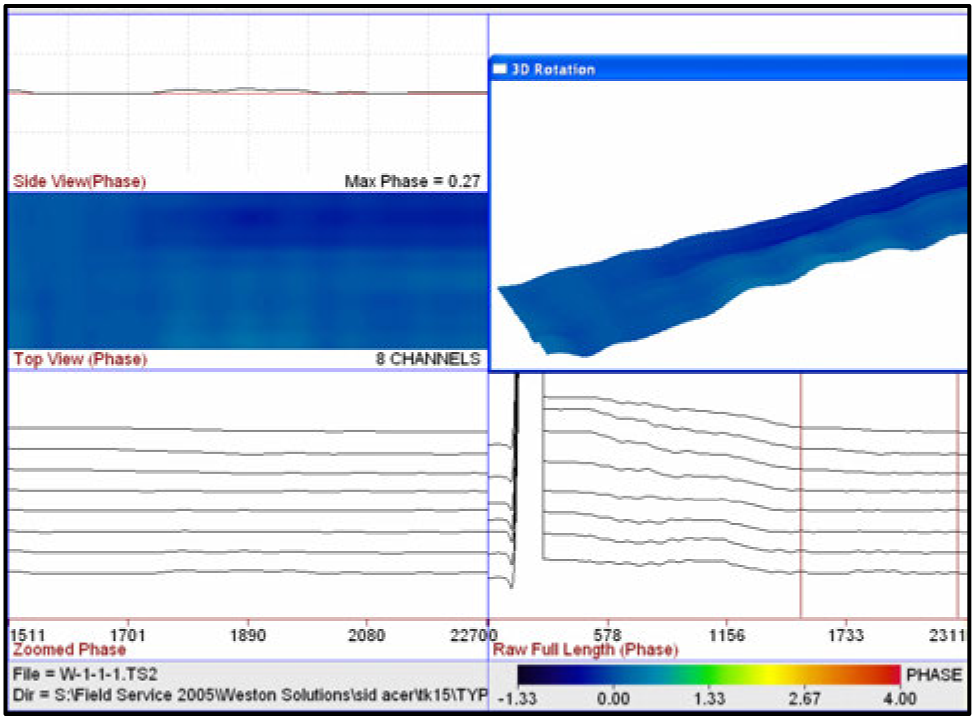

Figure 7. Example of an LFET scan showing non-indication of defects (nominal plate thickness of 0.250 inch).

- Upon approval the Government will direct the tank inspection contractor where to cut out coupons. Following is subject to NDE scan results:
  - o One coupon from the upper dome just above spring line.
  - o Cut-out two to four coupons from the barrel. Coupons will be from opposite sides of the Barrel, with at least one taken from the upper part of the Barrel and one from the lower part. The lower coupon shall be taken from just above a horizontal butt welded joint between the 19.6' x 5.0' shell plates.
  - o Cut-out one or two coupons from the lower dome. Coupons are to be taken from the sloping plate in the second course up from the flat bottom plate just above a horizontal butt welded joint.
  - o Cut-out one coupon from the lower dome (½" bottom plate.)
  - o Cut-out up to four additional coupons at random locations based on the LFET or BFET scans.
- Regulators have suggested that they should be invited to witness the testing. Safety is a top priority for the Navy with a goal of ZERO accidents/incidents. All observers must meet Navy security requirements and comply with Navy and contractor safety requirements (personal protective, safety training, etc.). In addition, due to the limited personnel baskets in the tanks, observers will only be able to witness the testing from the catwalk, not the basket.
- A Government representative will perform on-site testing, record observations, and ensure coupons will be preserved in accordance with ASTM E1188 when sending for third party laboratory analysis.
- NAVFAC EXWC will review the lab results to ensure they are acceptable in

accordance with the requirements of the contract. Provide third party analysis results to regulators for review.

- If no detrimental comments from the regulators, end coupon sampling unless additional coupons are necessary and time is available to obtain additional coupons. Agreement between past and current NDE scans of areas not repaired after the past scans will demonstrate the repeatability of the NDE process and further confirm its accuracy and credibility. Future coupon sampling will be as indicated in the TIRM report or as modified during efforts under Section 5.4 of the AOC-SOW.

3.2.7 Coupons from Pre-Prepared Steel Plates

Due to the potential of operational and tank inspection schedule constraints, the Navy will concurrently pursue the option of testing pre-prepared plates that has been suggested by several subject matter experts. The pre-prepared plates will have anomalies artificially created to simulate the defects of interest in the Red Hill Tanks. A tank inspection contractor will be tasked to scan the plates placed against a concrete surface to simulate the steel-concrete interface of the Red Hill Tanks. Although the pre-prepared plates will not necessarily be representative of actual Red Hill tank plates, the intention is to validate the technology and calibration of the equipment is good not just for Red Hill tanks but other types of tanks constructed of different type of steels, further increasing confidence in the validity of the scanning process. This will also provide additional samples to those obtained from Tank 17 or/and 14 to add to the statistical analysis of the validity of the scanning process and its independence on a particular site. Regulators will be invited to witness the testing which will have less safety constraints as compared to those for entering the Red Hill tanks.

3.2.8 **[OPTION]** Coupons from Tanks 1 and 19

Concurrent with the testing of tanks 17 or/and 14 and testing of pre-prepared plates, the Navy/DLA will pursue funding and a contracting process to conduct testing and coupon sampling in Tanks 1 and 19. The entire tank need not be scanned, just large enough sections to allow removal of coupon of sufficient size to validate the NDE results. The Government will identify five to ten sites and coupon sizes. This option is dependent upon the special funding being obtained in time to complete the testing within the AOC-SOW timeline of the Destructive Testing Report. In addition, due to its age and condition, establishing safe shell access, tower inspection and repairs, lighting, and ventilation, in Tank 1 may not be practicable, and testing may only be practicably done on the lower part of the lower dome. If this work can be executed within the AOC-SOW timeline, Regulators will be invited to review coupon site selection rationale, and witness the testing (must comply with all security and safety requirements). Except for maybe in the lower dome area, observers will only be able to witness the testing from the catwalk, not the basket.

3.2.9 **[OPTION]** Coupons from Other Tanks Outside Red Hill

A highly recommended and more practicable option to obtain coupons from Tanks 1 and 19, the Navy will pursue funding and a contracting process to conduct testing and coupon sampling in other tanks not located at Red Hill concurrent with the testing of Tank 17 or/and 14. The purpose of this alternative testing is to validate the results of the NDE per the goals of this AOC-SOW section, although the plates will not be representative of the condition of the Red Hill tanks. The intention is to validate the technology and calibration of the equipment is good not just for Red Hill tanks but other types of tanks constructed of different type of steels, further increasing confidence in the validity of the scanning process. This will also provide additional samples to those obtained from Tank 17 or/and 14 to add to the statistical analysis of the validity of the scanning process and its independence on a particular site. Regulators will be invited to witness the testing (must comply with all security and safety requirements).

3.2.10 Summary of Coupon Quantity, Size and Decision Process

The following bullets summarize the coupon sampling process. ***Figure 2*** is a flow chart of the process.

- Tank 17 or/and 14
    - The Contractor is to conduct NDE (3rd quarter calendar year (CY) 2017). The Regulators will be invited to observe the examinations at an agreed upon time.
    - The Government will analyze the data and select coupon sites (seek feedback from Regulators).
    - The contractor will obtain the coupons. The Regulators will be invited to observe this work at an agreed upon time. The Government will then conduct the visual examinations and on-site testing (UT, pit gauge, etc).
    - The coupons will be packed and shipped per ASTM E 1188.
    - The certified third-party laboratory will conduct the testing and ROC curve analysis.
    - A determination will be made by the Government if additional coupons are necessary based upon the ROC curve analysis.

- Pre-Prepared Plates
    - The Government will pursue funding upon approval of the SOW.
    - The contractor is to conduct NDE (fourth quarter CY 2017 through first quarter CY 2018). The Regulators will be invited to observe the examinations at an agreed upon time.
    - The Government will analyze the data and select coupon sites (seek feedback from Regulators).
    - The contractor will then obtain the coupons. The Regulators will be invited to observe this work at an agreed upon time. The Government will then conduct the visual examinations and on-site testing (UT, pit gauge, etc).
    - The coupons will be packed and shipped per ASTM E 1188.

- The certified third-party laboratory will conduct the testing and ROC curve analysis.
- A determination will be made by the Government if additional coupons are necessary based upon the ROC curve analysis.

- **[OPTION]** Tanks 1 and 19
  - The Government will pursue special funding upon approval of the SOW.
  - The contractor is to conduct NDE (third quarter calendar year CY 2017 through fourth quarter CY19). The Regulators will be invited to observe the examinations at an agreed upon time.
  - The Government will analyze the data and select coupon sites (seek feedback from Regulators).
  - The contractor will then obtain the coupons. The Regulators will be invited to observe this work at an agreed upon time. The Government will then conduct the visual examinations and on-site testing (UT, pit gauge, etc).
  - The coupons will be packed and shipped per ASTM E 1188.
  - The certified third-party laboratory will conduct the testing and ROC curve analysis.
  - A determination will be made by the Government if additional coupons are necessary based upon the ROC curve analysis.

- **[OPTION]** Other Tanks Outside Red Hill
  - Government pursue special funding upon approval of the SOW.
  - The contractor is to conduct NDE (second through third quarters of calendar year CY 2018). The Regulators will be invited to observe the examinations at an agreed upon time.
  - The Government will analyze the data and select coupon sites (seek feedback from Regulators).
  - The contractor will then obtain the coupons. The Regulators will be invited to observe this work at an agreed upon time. The Government will then conduct the visual examinations and on-site testing (UT, pit gauge, etc).
  - The coupons will be packed and shipped per ASTM E 1188.
  - The certified third-party laboratory will conduct the testing and ROC curve analysis.
  - A determination will be made by the Government if additional coupons are necessary based upon the ROC curve analysis.

Testing of the steel for other tanks beyond the requirements of this section is as indicated in the TIRM report. Subsequent to the work in this Section 5.3 of the AOC-SOW, Section 5.4 of the AOC-SOW will provide opportunity to discuss possible modifications to TIRM procedures.

4.0 OTHER ON-SITE AND LABORATORY TEST PROCEDURES

4.1 On-Site Investigations By Government (NAVFAC EXWC).

4.1.1 Characterization of the Exterior and Interior of the Steel Coupon

Table 3 is in the form of a field inspection data sheet that provide guidelines for the tests and observations that may be conducted for the steel coupon. In addition, the Navy may pursue positive material identification by Optical Emission Spectroscopy as described in the TIRM Report.

4.1.2 Exterior Concrete Containment

Conduct the following procedures for evaluating the concrete containment immediately upon removal of coupon.

- Note the condition of the concrete.
- Observe/measure the void space between the concrete and the liner in the area surrounding the coupon site. Check to determine if the material behind the coupons taken from the lower dome is grout or concrete.
- Measure the temperature at the concrete/liner interface. Note the presence of moisture. Also measure pH of exposed medium (if wet).
- Measure the structure-to-electrolyte potential of the steel liner-to-concrete/ exposed medium at several locations around the circumference of the coupon site.
- Measure concrete bulk resistivity (or conductivity), pH, and moisture content at the liner/concrete interface. ***Table 4*** is in the form of a field inspection data sheet that provide guidelines for the tests and observations that may be conducted for the concrete. Take concrete samples of sufficient size at three locations to aid in measurement of these characteristics. Anticipated sites are one each from opposite sides of the barrel, and one from the lower dome. The intent is to obtain powder samples for conducting the chemical tests of the concrete at different depths. The Navy has considered the suggestion of obtaining 4-inch diameter cores to the rock behind the concrete, but does not plan to include this effort as it could damage the extensive reinforcing steel and weaken the concrete structure as well as introduce moisture that could initiate corrosion. In addition, this deep coring effort provides no additional information relative to verifying the findings of the Corrosion and Metal Fatigue Practices Report per AOC-SOW Section 5.3.
- Test any contaminants at the coupon site, chlorides, sulfates/sulfides, biological materials. Note evidence of hydrocarbons.

4.2 Third Party Laboratory Analysis

Laboratory testing will include:

- Metallurgical/chemical analysis of the coupons in accordance with ASTM G1 Standard Practice for Preparing, Cleaning, and Evaluation Corrosion Test Specimens. Determine the physical and mechanical characteristics of the liner steel and weldments.
    - Chemical analysis of corrosion products and coatings.
    - Chemical analysis to evaluate for conformance with any specification.
    - Microscopic examination of surfaces, before and after cleaning. Examination and analysis of metallographic sections, determine microstructure.
    - Hardness measurements, bulk and cross-sectional.
    - Tensile testing, establish yield strength, ultimate tensile strength, and ductility.
    - Fatigue evaluation - establish endurance limit.
    - Evaluate results for validation of conformance with any material specification(s).
  - Characterization of the exterior and interior of the steel coupon.
  - Chemical analysis (bulk resistivity or conductivity, pH, and moisture content) of concrete powder samples taken as indicated in 4.1.2.
  - Statistical analysis utilizing the Receiver Operating Characteristic analysis.
  - Qualitative analysis of coupons to validate NDE process for detecting non-indication areas.

New TIRM procedures for Red Hill currently include destructive testing for metallurgical/ chemical analysis.

5.0 REPAIR OF COUPON SITES

Coupon sites will be repaired in accordance with current TIRM procedures and other applicable repair requirements identified in the inspection/repair contract Statement of Work for repairs.

Table 3. Characterization of Steel Coupon

COUPON SPECIFICS		
Coupon ID #		
Coupon Location		
Coupon Dimensions		
Coupon Thickness		
Locations of Welds (If Any)		
VISUAL EXAMINATION		
Checks	**Observations**	
	Exterior	Interior
Deposits, Coatings, Debris		
Scale		
Biological Materials		
Wet or Dry		
Smell		
Presence of Petroleum Product Between Steel and Concrete Surface, and on or Above the Leg of the Angle Backer Bar Embedded in the Concrete.		
Provide a sketch of the coupon showing the size and any indications. Provide ID#s for all indications on coupon		
Presence of Corrosion		
Isolated pitting		
Isolated pitting within areas of general corrosion		
Linked pitting within areas of general corrosion		
General metal loss with some deeper pits		
General metal loss with no pitting		
Selective attack at welds		
Pit surface and cross section morphology		
Severity of Corrosion		
Maximum wall loss		
Profile of wall loss		
Maximum/average pit depth		
Maximum/average pit diameter		
Pit length vs pit width		
Depth to diameter ratio		
Provide a photo and/or narrated video documentation of the coupon and backside conditions		

Table 4. On-site Visual Inspection and Testing of Concrete

CONCRETE SAMPLE SPECIFICS		
Sample ID #		
Sample Location		
Sample Dimensions		
ON-SITE TESTS/VISUAL EXAMINATION		
Checks	**Observations**	
	Exterior	Interior
Void space between concrete and liner (if any)		
Biological Materials		
Wet or Dry		
Smell		
Temperature		
Surface pH		
General condition		
Provide a photo and/or narrated video of the concrete and core (if taken)		

6.0 IMPLEMENTATION PLAN

6.1 Method of Accomplishment

It is intended that the destructive testing work under this section will be conducted as summarized in ***Table 5*** and described in the paragraphs that follow. The process for pre-prepared plates will be similar but with differences as indicate in ***Table 6***.

Table 5. Red Hill Tank Destructive Testing Work Performance Summary

Destructive Testing Process	Work Performance	Quality Assurance
NDE	Tank inspection/repair contractor	NAVFAC EXWC
Data Analysis and Coupon Site Selection	NAVFAC EXWC	Regulator/SME review
Obtaining Coupons	Tank inspection/repair contractor	NAVFAC EXWC. Possible observation by Regulators
On-site Examination and Testing at Coupon Site	NAVFAC EXWC	NAVFAC EXWC SMEs. Possible observation by Regulators
Coupon Packing/ Preservation for Lab Analysis	Tank inspection/repair contractor/NAVFAC EXWC	NAVFAC EXWC. Possible observation by Regulators
Analysis of Coupons	Third Party Laboratory	NAVFAC EXWC. Regulator/SME review

- LFET/BFET and proof scanning will be conducted by the tank inspection/ repair contractor as part of the tank inspection contract.
- NAVFAC EXWC will analyze the NDE inspection data and select coupon sites. Feedback will be solicited from the regulators.
- Coupons will be obtained by the tank inspection/repair contractor under direction from the Government. A new contract task order must be awarded after funding for the effort is received. NAVFAC EXWC will provide quality assurance and will be involved in conducting the on-site testing and examination.
- Coupons will be sent to a third part laboratory for metallurgical and statistical analysis. A new contract must be awarded after approval of this scope of work and funding for the effort is received. NAVFAC EXWC will provide quality assurance. Feedback will be solicited from the regulators.

Table 6. Pre-prepared Plates Testing Work Performance Summary

Destructive Testing Process	Work Performance	Quality Assurance
Prepare Steel Plates	NAVFAC EXWC	NAVFAC EXWC
NDE	Tank inspection/repair contractor	NAVFAC EXWC. Possible Regulator/SME observation
Coupon Packing/ Preservation for Lab Analysis	Tank inspection/repair contractor/NAVFAC EXWC	NAVFAC EXWC. Possible observation by Regulators
Analysis of Coupons	Third Party Laboratory	NAVFAC EXWC. Regulator/SME review

6.2 Proposed Schedule

A summary of the planned schedule is indicated below based on the assumption that this SOW will be approved during the third quarter of calendar year (CY) 2017. Figure 8 is a graphical representation of the project schedule.

- The inspection/repair contract for Tanks 17 and 14 was awarded on 31 August 2016. The contract will need to be modified in order to remove the coupons and repair the tank where the coupons were removed.
- The Tank 17 and 14 NDE is planned to occur during the third quarter of calendar year (CY) 2017.
- Determination of destructive testing coupon sites is planned upon completion of analysis of NDE test data during the period between the fourth quarter of CY 2017 and first quarter of CY2018.
- Coupon removal and on-site examination is anticipated to occur during the first quarter of CY 2018:
- Third party laboratory analysis will occur subsequent to removal of the metal or concrete sample. Anticipated time-frame is during the first to second quarters of CY 2018.
- Concurrently with the Tank 17/14 effort, conduct NDE testing and laboratory analysis of pre-prepared plates during fourth quarter of CY 2017 through the second quarter of CY 2018.
- Time is also allowed for additional coupon sampling and analysis during the second through third quarters of CY 2018 (if a tank is available) with subsequent laboratory analysis during third through fourth quarters of CY 2018.
- **[OPTION]** Also concurrently with the Tank 17/14 effort, pursue conducting NDE testing and laboratory analysis of Tanks 1 or 19 during the second through third quarters of CY 2018 only if the special funding is available and the tanks can be cleared for safe entry.
- **[OPTION]** The Navy will pursue NDE testing and laboratory analysis of other tanks outside Red Hill during the second through fourth quarters of CY 2018 if funding is available and tanks are available for such work.
- A draft Destructive Testing Report is planned for completion by the first

quarter of CY 2019 with the final to be completed by the second quarter of CY 2019 (2 years from approval of this scope of work). It may be possible to complete the final report earlier if the "Tank 1/19" and "Other Tanks" options cannot be completed within the required timeframe.

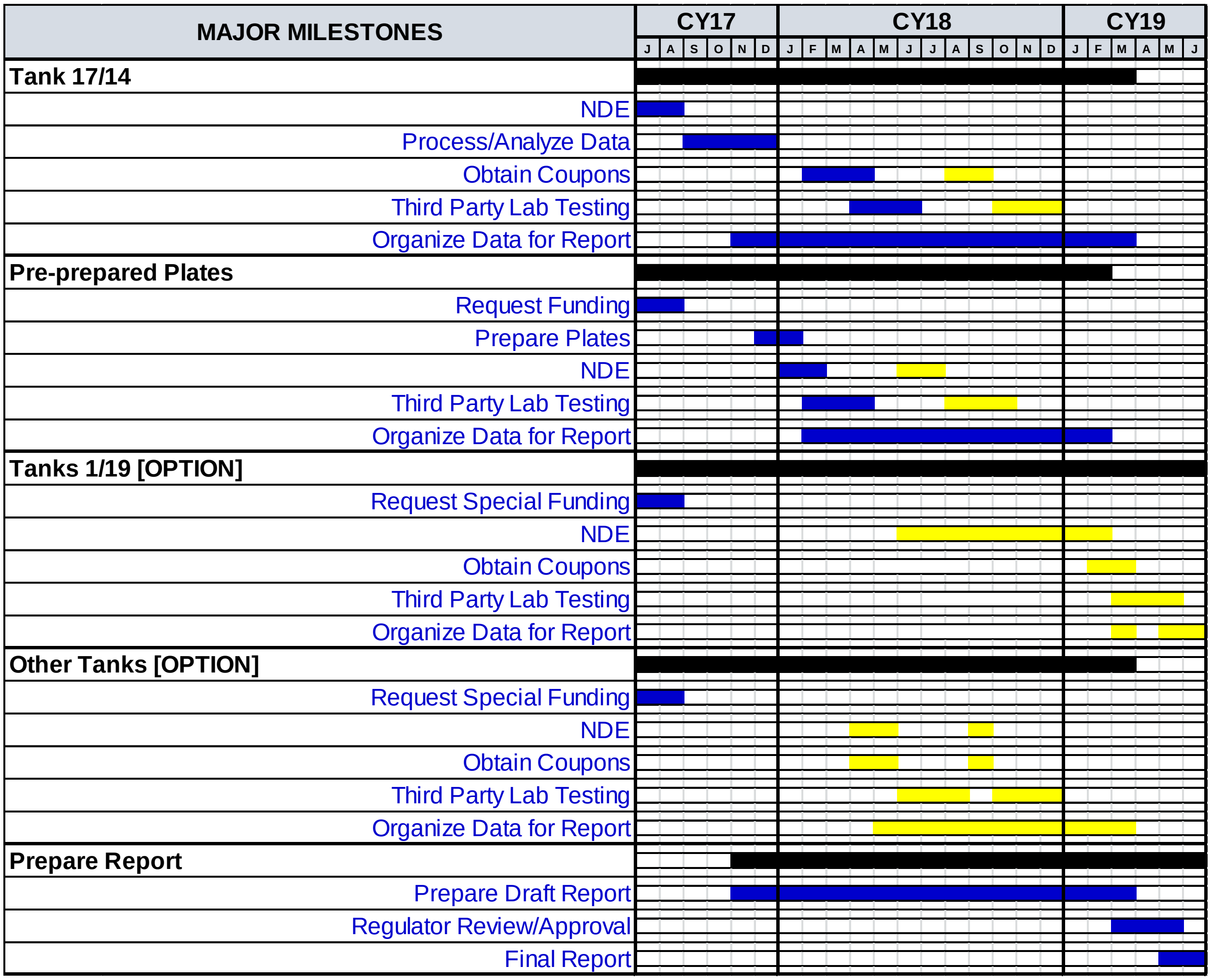

Figure 8. Project Schedule

<u>Notes for Figure 8:</u>

1. Time schedules in blue indicate performing the work.
2. Time schedules in yellow are contingent upon funding availability, safe entry, and tank availability.
3. Contracting line items are not shown, however, timing in the schedule allows for such efforts.
4. Separate line items are not shown for preparing tank for safe entry but are accounted for in the timelines.

7.0 REPORT CONTENT

The Destructive Testing Report will provide detailed discussions of the destructive testing examination effort including discussions of test processes and rationale, tabulation of test data, identification of appropriate reference criteria or standards, and narrative explanation of the results including:

- Correlation of destructive testing data/observation with NDE test data
- Records of on-site visual examinations and tests
- Analysis of corrosion rate calculation procedures and recommendations for improvement
- Evaluation of results against current corrosion mitigation practices and recommendations for modifications/improvements to TIRM procedures and tank upgrade alternatives.
- Recommendations for additional destructive testing

Upon approval of the report the Navy and Regulators will proceed into scoping meetings as necessary in accordance with AOC-SOW Section 5.4 to address any needs for further evaluation, development, or implementation of practices to control corrosion or metal fatigue.

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APPENDIX A

GLOSSARY

ACRONYMS

AOC	Administrative Order on Consent
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
BFET	Balanced Field Electromagnetic Technique
CY	Calendar Year
DE	Destructive Examination
DLA	Defense Logistics Agency
DoD	Department of Defense
DOH	(State of Hawaii) Department of Health
EPA	Environmental Protection Agency
LFET	Low Frequency Electromagnetic Technique
MT	Magnetic Particle Testing
NAVFAC	Naval Facilities Engineering Command (NAVFACENGCOM)
NAVFAC EXWC	NAVFAC Engineering and Expeditionary Warfare Center
NDE	Non Destructive Evaluation
pH	A measure of hydrogen ion activity
ROC	Receiver Operating Characteristic
SOW	Statement of Work
SWUT	Shear Wave Ultrasonic Testing
TIRM	Tank Inspection, Repair and Maintenance
TUA	Tank Upgrade Alternatives
UST	Underground Storage Tank
UT	Ultrasonic Testing

DEFINITION OF TERMS

Coating: A dielectric material applied to a structure to separate it from its environment.[1]

Conductivity: The measurement of a material's ability to conduct electrical current.

Corrosion: The deterioration of a material or its properties due to a reaction of that material with its chemical environment.

Corrosion rate: The rate at which corrosion proceeds.[1]

Defect: Flaw whose characteristics or properties do not meet acceptance criteria and is rejectable.

Electrode: A conductor used to establish electrical contact with an electrolyte and through which current is transferred to or from an electrolyte.[1]

Electrolyte: A chemical substance or mixture containing ions that migrate in an electric field. Examples are soil and seawater.

Evaluation: Determination whether a relevant indication is cause to accept or reject (the repair).

Flaw: Imperfection or discontinuity detectable by nondestructive testing; not necessarily rejectable.

Galvanic cell: A corrosion cell in which anode and cathode are dissimilar conductors, producing corrosion because of their innate difference in potential.

Galvanic corrosion: Corrosion resulting from the coupling of dissimilar metals in an electrolyte.

Holiday: A discontinuity in a coating that exposes the metal surface to the environment.

Imperfection: Departure of a quality characteristic from its intended condition.

Indication: Results of a non-destructive examination.

Interpretation: Determination whether an indication is relevant, non-relevant, or false.

Optical Emission Spectroscopy: An analytical technique used to determine the elemental composition of a broad range of metals. An OES analyzer works by emitting an electric arc onto a sample, whose atoms transmit an elemental signature of light to the analyzer. The analyzer then processes the incoming light signals to determine the elemental composition of the sample.

pH: A measure of hydrogen ion activity defined by: $pH = \log_{10} (1/aH^+)$ where aH^+ = hydrogen ion activity = molal concentration of hydrogen ions multiplied by the mean ion activity coefficient (= 1 for simplified calculations).

Pitting: Localized corrosion of a metal surface that is confined to a small area and takes the form of cavities called pits.

Relevant Indication: An NDT indication that requires evaluation.

Resistivity: The measurement of a material's ability to oppose the flow of electric current.

Rust: A reddish-brown corrosion product of iron that is primarily hydrated iron oxide.

Safe Shell Access: Compliance with the ventilation, degassing, confined space, and other safety requirements when entering fuel storage tanks. Refer to the TIRM Report

Structure-to-electrolyte potential (also structure-to-soil potential): The potential difference between a buried metallic structure surface and electrolyte that is measured with reference to an electrode in contact with the electrolyte. See also pipe-to-soil potential.

(Wall) Thinning (Uniform corrosion): Corrosion attack of a metal that is essentially the same at all exposed areas of its surface.